Effect of Planting Media Modification on Seed Growth and Development of Three Mangroves Species from Jakarta and Kebumen, Indonesia

Erwin Riyanto Ardli[1], Wahdini Hanifah[2], Romanus Edy Prabowo[1], Bayu Ashila Nafis[1], Dwi Sunu Widyartini[1]

[1] Faculty of Biology, Universitas Jenderal Soedirman
Jl. Dr. Soeparno 63 Grendeng Purwokerto, Indonesia 53122
[2] Institute of Climate Adaptation and Marine Biotechnology, Universiti Malaysia Terengganu
21030 Kuala Nerus, Terengganu.
Email: erwin.ardli@unsoed.ac.id

Abstract

The rehabilitation of mangroves depends on the availability of high-quality, sufficiently prominent seeds. Currently, a lot of mangrove nursery activities continue to employ traditional techniques, which results in low-quality and slowly growing seedlings. The mangroves of Jakarta were selected because they represent a heavily polluted mangrove ecosystem on Java's northern coast, whereas the mangroves in Kebumen, on Java's southern coast, are in the opposite situation. This study proposed to find an approach to supply Indonesia's mangrove restoration projects with adequate seeds. An experimental approach with a complete randomized design and a factorial pattern was used. The variables tested were planting media and three kinds of mangroves: Rhizophora mucronata, Ceriops tagal, and Bruguiera gymnorrhiza. Mangroves from Jakarta are treated with mud, soil media, or a mix of them. A mixture of mud, husk, and husk charcoal is used for six treatments planting media for mangroves from Kebumen. The mangrove seedlings' growth, biomass, and chlorophyll content are the dependent variables. ANOVA was used to evaluate the data with a 95% confidence level, and Duncan's comparison of means test followed. The growth of mangrove seedlings was discovered to be impacted by media type, while the chlorophyll content, dry biomass of roots, stems, and leaves were not affected by this factor. Three species of mangroves differ regarding growth rate, biomass of roots, stems, and leaves, and chlorophyll content. In order to support Indonesia's efforts to rehabilitate mangroves, this research can offer understanding regarding how to select and employ the best media to effectively produce high-quality seeds.

***Keywords**: Nursery; Propagule; Ceriops; Bruguiera; Rhizophora.*

Introduction

The goods and services that mangrove ecosystems offer serve as essential for both the environment and people (Getzner and Islam, 2020). Mangroves provide a variety of resources and commodities, such as wood, fuel, fibre, food, medicine, colors, and others (Lin *et al.*, 2022; Ramesh *et al.*, 2022). Mangrove habitats provide a wide variety of ecological and environmental services, such as supporting and regulating roles. Additionally, mangroves provide cultural services or human culture (Clough, 2013). Serving as a nursery, spawning site, and feeding ground for marine and estuarine biota, which includes biota that has important economic value, are instances ecological supporting services (Ardli *et al.*, 2015).

The mangrove environment is an ecological asset that offers numerous benefits to the people who live in surrounding areas of the ecosystem (Anu *et al.*, 2024). In addition to their ecological roles, mangroves are one of the primary marine fisheries producers (Tomlinson, 1994; Giesen *et al.*, 2007; Ardli *et al.*, 2015). Mangroves contribute to the carbon, nitrogen, and sulphur cycles by producing nutrients that may enrich marine environments (Yuwono *et al.*, 2007). Mangroves are able to sustain fish, crustacean, shellfish, and other biota populations due to their high primary production (Abrogueña *et al.*, 2012). In addition, a number of animal species find food and breeding grounds in mangroves (Anneboina and Kumar, 2017).

Over the past four decades, mangrove ecosystem services and functions reduced due to with damage and shrinkage of mangrove areas. This causes a number of issues, such as diminished fisheries productivity, decreased mangrove diversity, habitat and nursery area loss, decreased mangrove and water productivity, pollution, acidification of the soil, and intrusion of seawater (Ardli and Wolff, 2009; Koswara *et al.*, 2017; Ardli *et al.*, 2022). There are 3.3 million hectares of mangrove forests in Indonesia (Nurbaya, 2020), with approximately 182,091 hectares lost during the 2009–2019 period (Arifanti

*) Corresponding author

https://ejournal.undip.ac.id/index.php/ijms
DOI: 10.14710/ik.ijms.29.2.285-292
Received : 28-01-2024
Accepted : 05-04-2024

et al., 2021), that require immediate rehabilitation. The availability of seeds that are high-quality and sufficient in quantity for rehabilitation projects is one challenge that needs to be resolved.

Almost all of Indonesia's mangrove habitats are dominated by the genus Rhizophora. In damaged areas, mangrove restoration actions frequently use various species of this genus derived from various research. The reasoning for which is since Rhizophora seedlings have a wide tolerance range for salinity (Basyuni *et al.*, 2018), easy growing at various substrates and soil (Amaliyah *et al.*, 2018), found on the coast of southern Java such as Segara Anakan (Nordhaus *et al.*, 2019). *Ceriops* is often found in quite dominant numbers in the coastal areas of southern Java (Koswara *et al.*, 2017; Nordhaus *et al.*, 2019; Rahman *et al.*, 2019). The availability of sufficient amounts of high-quality mangrove seeds can provide difficulties to mangrove rehabilitation activities. In addition to it, there is not a simple, effective way for mangrove seeding. As a result, studies on mangrove seeding techniques and media adjustments are required. The aim of this study is to find out the planting media that provides optimal influence on the growth of *Bruguiera gymnorrhiza, Rhizophora mucronata* and *Ceriops tagal* seedlings, and to find out the best seeding methods for Rhizophora*,* Bruguiera and Ceriops.

Materials and Methods

Seeding and field data collection were carried out on Angke Kapuk Jakarta Nature Tourism Park (TWA) 6.10638362S, 106.736159E and Kebumen beach, Central Java at coordinates 07°34'29.42" S - 07°47'32.39" S; 108°46'30.12" E-109°03'21.02" E.

The research was carried out experimentally with a Factorial Completely Randomized Design (Factorial-CRD) with six levels of planting media to be tested in Kebumen. These levels are M1: Mud, M2: Mud + Husk (1:1), M3: Mud + Husk (2:1), M4: Mud + Husk charcoal (1:1), M5: Mud + Husk charcoal (2:1), and M6: Mud + Husk charcoal + Husk (1:1:1), respectively. While three levels of planting media which are mud; soil; and mud+soil (1:1) where applied in TWA Jakarta. Each levels of planting media were repeated 10 times. The experiment was conducted in a 10 cm × 15 cm plastic polybag.

Variables observed consist of dependent and independent variables. The independent variable is the planting medium which consist of 6 and 3 levels of treatment, and three species of mangroves. While, the dependent variables are the biomass of root, stem, leaves, and also chlorophyll content of mangrove leaves. The primary parameter is the high of seeding, the biomass which consist of dry weight of root, stem, leaves, and chlorophyll content of mangrove leaves. The secondary parameter are water content, carbon content, pH, and N, P, K content in the media. Parameters were measured every week up to eight weeks.

Biomass measurement was done by destructive harvesting. Following harvesting, the seedlings were cleaned and separated into sections based on the leaf, branch, stem, and root sections. These were dried for 72 h at 70°C until a consistent weight was reached. With an accuracy of ±0.003g, the oven-dry mass was measured to the milligram using the standard laboratory scale (Bebre *et al.*, 2021). Organic solvents (80% acetone) are used in destructive procedures for the measurement of chlorophyll. To inhibit the activity of chorophllase, 0.25g of leaf sample was ground in 2ml of 80% acetone with sand (0.1% or 0.1 $CaCO_3$). After the samples were filtered through filter papers to a final volume of 25 ml, they were put into a spectrophotometer to measure absorbency (A663 and A646). The absorbency was determined using equations 1, 2, and 3 (Ali *et al.*, 2021).

$$\mathrm{Cha} = 12.25(\mathrm{A}_{663}) - 2.79(\mathrm{A}_{646}) \quad (1)$$

$$\mathrm{Chb} = 21.5(\mathrm{A}_{646}) - 5.1(\mathrm{A}_{663}) \quad (2)$$

$$\text{Total Chlorophyll} = \frac{5.24\times(\mathrm{A}_{663})+22.24\times(\mathrm{A}_{646})}{\mathrm{FW}} \quad (3)$$

ANOVA was used to examine the data with a 95% confidence level. If a variable significantly affects the response, the Duncan's comparison of means test was applied.

Result and Discussion

The mangrove nursery in Kebumen shows that planting media has an influence on the growth rate of both mangrove plants which are *B. gymnorrhiza*, *R. mucronata* and *C. tagal*. The three mangrove species showed significant differences in growth rates (P= 0.000); *B. gymnorrhiza* grows at the fastest rate, 1.35 cm per week, followed by growth *R. mucronata* (0.97 cm per week) and *C. tagal* (0,09 cm per week). The differences of planting media were also affecting the mangrove growth significantly (P= 0.020). The analysis of planting media, it shows that the mud:husk-charcoal 1:1 (T4) mixture has the significant influence on mangrove growth, followed by other planting media combinations (Table 1.).

The growth rate of the *B. gymnorrhiza* using a mixed planting medium of mud and husk charcoal was 1.35 cm.week^{-1}, this result is much greater than other studies using ordinary mud as a planting medium which about 0.33 cm.week^{-1} (Permatasari and Kusmana, 2011). Whereas, the results of this study are somewhat similar with the findings of Prambudy *et al*. (2023) research, which planted *B. gymnorrhiza* at a growth rate of 1.40 $cm.week^{-1}$ in soil media. The husk charcoal and mud mixture provides a cavity in the soil between the soil particles that maintains water and increases the amount of soluble nutrients. The data shown in Table 2 indicates the treatment with the highest water content also had the highest concentration of phosphate (0.045%). Other nutrition elements, though, have not altered as significantly.

Husk and husk charcoal can be used as a nursery media to unlock the soil. A good nursery media in mangrove nurseries is one which is not excessively dense. This will facilitate the growth and development of plant roots, and can also help absorption of water, air, and nutrients properly. Another can easily obtain the media at a relatively low price (Dewi *et al.*, 2020). Research findings related to Figure 3, which indicates that the T4 (mud:husk charcoal 1:1) treatment had the highest root biomass, particularly in *B. gymnorrhiza* and *R. mucronata*, additionally reinforce this perspective. According to Taek (2016), husk charcoal has a pH of 6.8 and contains 0.3% N, 15% P_2O_5, 31% K_2O, and a number of other minerals. As a soil restoration material, husk charcoal can enhance plant growth and improve soil characteristics in land rehabilitation (Kusuma *et al.*, 2013).

Several environmental factors influence the growth of mangrove propagule or seeds, such as light intensity (Kathiresan and Rajendran, 2002), precipitation and climate (Kodikara *et al.*, 2018; Riascos *et al.*, 2018), salinity (Basyuni *et al.*, 2018), fresh water supply and planting media (Auni *et al.*, 2020; Usman *et al.*, 2022), temperature and nutrient (Gillis *et al.*, 2019). Mangroves in their initial growth period require optimal conditions with minimal disturbing factors such as pests (Gaoue and Yessoufou, 2019).

The nutrients nitrogen, phosphorus, and Cation Exchange Capacity (CEC) are important for plant growth since they are involved in metabolic processes and end up as components of the plant's constituents. The mangrove nursery medium's total N concentration varied between 0.25 and 0.34%. The range of the P elements was between 0.038 and 0.045%, nevertheless the soil fertility is still low. P components in soil are derived from minerals, synthetic fertilizers, and organic materials. The amount of organic matter in the media affects the content of N and P elements. Due to the moderate amount of organic material present, the total P and N elements in all of the nursery medium used in this study are categorized as moderate.

The experiment conducted at the TWA Angke Kapuk Jakarta site that there is not a significant

Table 1. Duncan comparison means test of mangrove seeding based on growth rate ($cm.week^{-1}$) at Kebumen.

	Medium	N	Subset			Notation
			1	2	3	
Duncan[a]	M3 *C. tagal*	60	.0960			a
	M2 *R. mucronata*	60		.9679		b
	M1 *B. gymnorrhiza*	60			1.3479	c
	Sig.		1.000	1.000	1.000	
Duncan[a]	T3 Mud:Husk 2:1	30	.7075			a
	T5 Mud:HuskCharcoal 2:1	30	.7700			a
	T6 Mud:Husk:HuskCharcoal 1:1:1	30	.8104	.8104		ab
	T1 Mud	30	.8104	.8104		ab
	T2 Mud:Husk 1:1	30	.8204	.8204		ab
	T4 Mud:HuskCharcoal 1:1	30		.9050		b
	Sig.		.069	.121		

The error term is Mean Square (Error) = .046.
a. Uses Harmonic Mean Sample Size = 60.000 for mangrove and 30 for planting media

Table 2. Total macro nutrients, water content and total organic of the planting media.

Sampel	N total (%)	P (eks. HCl 25%) (%)	K ($me.100gr^{-1}$)	Water content (%)	Total Organic (%)
T1	0.30	0.039	0.26	16.89	9.42
T2	0.34	0.043	0.25	40.32	18.02
T3	0.26	0.044	0.31	23.75	14.13
T4	0.32	0.045	0.22	41.13	14.21
T5	0.29	0.041	0.28	25.17	9.02
T6	0.25	0.038	0.36	32.57	13.66

distinction in planting media between the growth of *B. gymnorrhiza* and *R. mucronata* mangroves (*P*= 0.320). Due to their dissimilar development rates and habitat ranges, *B. gymnorrhiza* and *R. mucronata* present different growth rates (*P*= 0.000). *R. mucronata* lives in the seaward zone, which is an area that is frequently inundated, has soft substrates, and is greater in salinity than the landward zone, where *B. gymnorrhiza* grows most ideally. Research on the *C. tagal* species was not conducted because there does not a species which lives the TWA Jakarta mangrove area.

Results showed that there were significant differences in both mangrove species and locations when *B. gymnorrhiza* and *R. mucronata* were compared for growth in two different locations (TWA Jakarta and Kebumen) (*P*= 0.000). In TWA Jakarta, both mangrove species are growing rapidly (Table 3.). *B. gymnorrhiza* grew significantly faster at the TWA Jakarta site because the media therein had a salinity of less than 11 ppt, which is suitable for this species growth, in contrast to the salinity of over twenty ppt at the Kebumen site.

The study's findings show that the total, a, and b chlorophyll contents are within the appropriate range (Figure 1.). The process of photosynthesis and plant metabolism are also indicated by the amount of chlorophyll present. Variations in leaf chlorophyll levels may provide information about the physiological condition of leaves or plants, considering chlorophyll content a necessary metric measurements (Kamble *et al.*, 2015). A plant's health is highly correlated with its chlorophyll level (Pérez-Patricio *et al.*, 2018).

Significant variations were observed between the three species of mangroves in terms of both total and chlorophyll-a concentration. The highest concentration of chlorophyll-a and total chlorophyll is found in *C. tagal*, which is followed by *R. mucronata* and *B. gymnorrhiza*. In contrast, there were no significant differences in chlorophyll-b amounts among these three species. At the Kebumen nursery, the chlorophyll-a content of *R. mucronata* ranges from 8.2 to 12.7 $mg.g^{-1}dw$, while that of *C. tagal* is 11.9-16.2 $mg.g^{-1}dw$ for chlorophyll-a and 6.7-9.0 $mg.g^{-1}dw$ for chlorophyll-b. This chlorophyll content is much higher than that of the investigations conducted by Herteman *et al.* (2011), which found that the chlorophyll-a content in *R. mucronata* was among 3.01 and 4.01 $mg.g^{-1}dw$, and in *C. tagal*, it was between 2.88 and 3.28 $mg\ g^{-1}dw$.

Table 3. Comparison of mangrove growth rate ($cm.week^{-1}$) were planted in TWA Jakarta and Kebumen.

Mangrove Species	TWA Jakarta	Kebumen
R. mucronata	1.59	1.09
B. gymnorrhiza	2.87	1.24

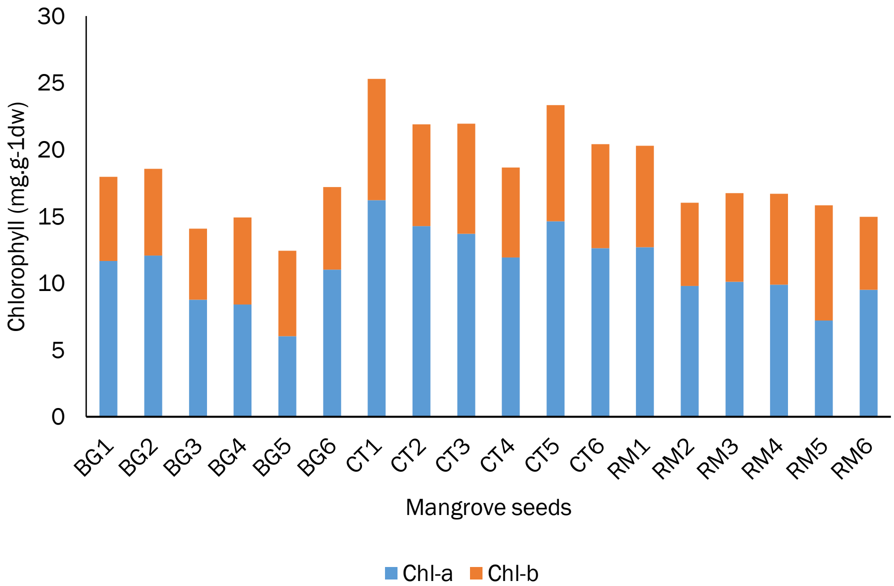

Figure 1. Chlorophyll content ($mg.g^{-1}dw$) of *B. gymnorrhiza* (BG), *C. tagal* (CT), and *R. mucronata* (RM). Number 1-6 indicates planting media (T1-T6).

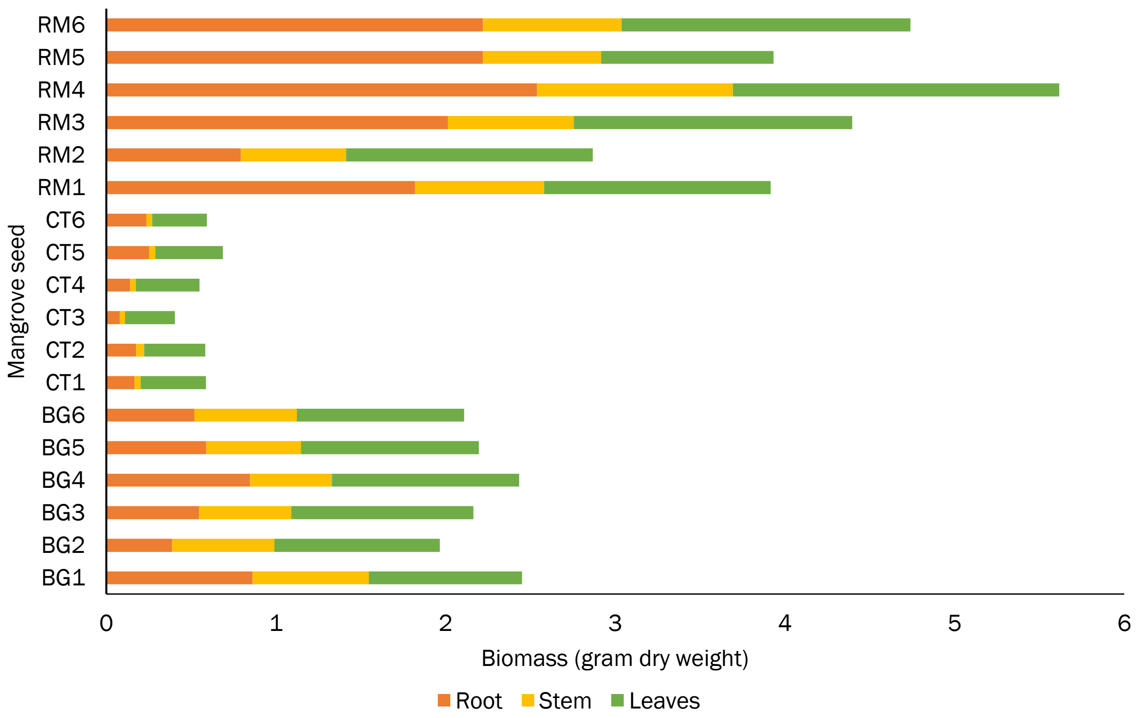

Figure 2. Biomass (gram dry weight) of *B. gymnorrhiza* (BG), *C. tagal* (CT), and *R. mucronata* (RM). Number 1-6 indicates planting media (T1-T6).

Several decades ago, mangrove areas in several regions in Indonesia experienced damage or disturbance (Ardli *et al.*, 2015) Sedimentation, inappropriate resource exploitation, illegal cutting of mangrove vegetation and conversion, population migration, and other factors such as the absence of stakeholder integration for sustainable management of mangrove areas or ecosystems are among some of the causes of the decline in circumstances (Yuwono *et al.*, 2007; Ardli and Wolff, 2009; Hinrichs *et al.*, 2009; Holtermann *et al.*, 2009; Prasetyo *et al.*, 2017). Information from this study is expected to exhibit that a number of input parameters, particularly an abundance of good-quality seeds, can affect the success of mangrove planting. In three years, the government plans to restore 600,000 hectares of mangroves, and this will help achieve the target considerably.

Conclusion

The growth of mangrove seedlings was found to be influenced by the type of media, yet unaffected through the chlorophyll content or the ash-free biomass of the roots, stems, or leaves. Three species of mangroves differ regarding growth rate, biomass of roots, stems, and leaves, and chlorophyll content. The study might offer knowledge about methods to select and employ the most appropriate media for effectively producing high-quality seeds, which would help Indonesia's efforts to rehabilitate mangroves.

Acknowledgement

We are grateful for the contributions made to the publication of this article by TWA Angke Kapuk Jakarta, KEE Mangrove Logending Kebumen, and the Department of Environmental Biology at Universitas Jenderal Soedirman. The research was funded by Universitas Jenderal Soedirman through Unsoed Basic Research (RDU grant).

References

Abrogueña, J.B.R., Bagarinao, T.U. & Chícharo, L. 2012. Fish Habitats in a Small, Human-impacted Sibunag Mangrove Creek (Guimaras, Philippines): A Basis for Mangrove Resource Enhancement. *Ecohydrol. Hydrobiol.,* 12(4): 311–319. https://doi.org/10.2478/v10104-012-0025-z

Ali, K.A., Noraldeen, S.S. & Yaseen, A.A. 2021. An Evaluation Study for Chlorophyll Estimation Techniques. *Sarhad J. Agric.* 37(4): 1458–1465. https://doi.org/10.17582/journal.sja/2021/37.4.1458.1465

Amaliyah, S., Hariyanto, S. & Purnobasuki, H. 2018. Growth responses of R*hizophora apiculata* Blume in different soil and sediment conditions. *AACL Bioflux,* 11(2): 379–386.

Anneboina, L.R. & Kumar, K.S.K. 2017. Economic Analysis of Mangrove and Marine Fishery Linkages in India. *Ecosyst. Serv.,* 24: 114–123. https://doi.org/10.1016/j.ecoser.2017.02.004

Anu, K., Henna, P.K., Sneha, V.K., Busheera, P., Muhammed, J. & Augustine, A. 2024. Mangroves in environmental engineering: Harnessing the multifunctional potential of nature's coastal architects for sustainable ecosystem management. *Results Eng.,* 21: 101765. https://doi.org/10.1016/j.rineng.2024.101765

Ardli, E.R., Widyastuti, A. & Yani, E. 2015. Kajian Perubahan Bioekologi pada Restorasi Ekosistem Mangrove di Segara Anakan Cilacap. *Biosfera,* 32(1): 19-28. https://doi.org/10.20884/1.mib.2015.32.1.291

Ardli, E.R. & Wolff, M. 2009. Land Use and Land Cover Change Affecting Habitat Distribution in the Segara Anakan Lagoon, Java, Indonesia. *Reg. Environ. Chang.,* 9: 235–243. https://doi.org/10.1007/s10113-008-0072-6

Ardli, E.R., Yuwono, E. & Purwanto, A.D. 2022. Land Cover Changes and Impacts of Massive Siltation on the Mangrove Segara Anakan Lagoon System, Cilacap Indonesia. *J. Ecol. Eng.,* 23(7): 29–41. https://doi.org/10.12911/22998993/149821

Arifanti, V.B., Novita, N., Subarno & Tosiani, A. 2021. Mangrove Deforestation and CO_2 Emissions in Indonesia. *IOP Conf. Ser. Earth Environ. Sci.,* 874(1): 012006. https://doi.org/10.1088/1755-1315/874/1/012006

Auni, A.H., Bachtiar, B., Paembonan, S.A. & Larekeng, S.H. 2020. Growth analysis of mangrove (*Rhizophora apiculata* bl) propagule toward differences in types of water and planting media at Makassar mangrove center. *IOP Conf. Ser. Earth Environ. Sci.,* 575(1): p.012137. https://doi.org/10.1088/1755-1315/575/1/ 012137

Basyuni, M., Telaumbanua, T., Wati, R., Sulistiono, N. & Putri, L.A.P. 2018. Evaluation of *Rhizophora mucronata* Growth at first-year Mangrove Restoration at Abandoned Ponds, Langkat, North Sumatra. *IOP Conf. Ser. Earth Environ. Sci.,* 126(1): p.012118. https://doi.org/ 10.1088/1755-1315/126/1/012118

Bebre, I., Riebl, H. & Annighöfer, P. 2021. Seedling growth and biomass production under different light availability levels and competition types. *Forests,* 12(10): p.1376. https://doi.org/10.3390/f12101376

Clough, B. 2013. Continuing the Journey Amongst Mangroves. Japan: International Society for Mangrove Ecosystems (ISME), Okinawa, International Tropical Timber Organization (ITTO), Yokohama, 1: 86.

Dewi, A.F., Sari, T.M. & Carolina, H.S. 2020. Pengaruh Media Tanam Pasir, Arang Sekam, dan Aplikasi Pupuk LCN terhadap Jumlah Tunas Tanaman Tin (*Ficus carica* L.) sebagai Sumber Belajar Biologi. *J. Bioeducation,* 7(1): 1–7. https://doi.org/10.29406/.v7i1.1727

Gaoue, O.G. & Yessoufou, K. 2019. Strong seedling recruitment does not limit mangrove vulnerability to harvest. *Environ. Res. Lett.,* 14(6): p.064019. https://doi.org/10.1088/1748-9326/ab1def

Getzner, M. & Islam, M.S. 2020. Ecosystem services of mangrove forests: Results of a meta-analysis of economic values. *Int. J. Environ. Res. Public Health,* 17(16): p.5830. https://doi.org/10.3390/ijerph17165830

Giesen, W., Wulffraat, S., Zieren, M. & Scholten, L. 2007. Mangrove guidebook for Southeast Asia. Bangkok: FAO Regional Office for Asia and the Pacific.

Gillis, L.G., Hortua, D.A.S., Zimmer, M., Jennerjahn, T.C. & Herbeck, L.S. 2019. Interactive effects of temperature and nutrients on mangrove seedling growth and implications for establishment. *Mar. Environ. Res.,* 151: p.104750. https://doi.org/10.1016/j.marenvres.2019.104750

Herteman, M., Fromard, F. & Lambs, L. 2011. Effects of pretreated domestic wastewater supplies on leaf pigment content, photosynthesis rate and growth of mangrove trees: A field study from Mayotte Island, SW Indian Ocean. *Ecol. Eng.,* 37(9): 1283–1291. https://doi.org/10.1016/j.ecoleng.2011.03.027

Hinrichs, S., Nordhaus, I. & Geist, S.J. 2009. Status, Diversity and Distribution Patterns of Mangrove Vegetation in the Segara Anakan Lagoon, Java, Indonesia. *Reg. Environ. Change,* 9: 275–289. https://doi.org/10.1007/s10113-008-0074-4

Holtermann, P., Burchard, H. & Jennerjahn, T. 2009.

Hydrodynamics of the Segara Anakan lagoon. *Reg. Environ. Change,* 9: 245–258. https://doi.org/10.1007/s10113-008-0075-3

Kamble, P.N., Giri, S.P., Mane, R.S. & Tiwana, A. 2015. Estimation of Chlorophyll Content in Young and Adult Leaves of Some Selected Plants in Non-Polluted Areas. *Univers. J. Environ. Res. Technol.,* 5(6): 306–310.

Kathiresan, K. & Rajendran, N. 2002. Growth of a mangrove (*Rhizophora apiculata*) seedlings as influenced by GA3, light and salinity. *Rev. Biol. Trop.,* 50(2): 525–530.

Kodikara, K.A.S., Jayatissa, L.P., Huxham, M., Dahdouh-Guebas, F. & Koedam, N. 2018. The effects of salinity on growth and survival of mangrove seedlings changes with age. *Acta Bot. Bras.,* 32(1): 37–46. https://doi.org/10.1590/0102-33062017abb0100

Koswara, S.D., Ardli, E.R. & Yani, E. 2017. the Monitoring of Mangrove Vegetation Community Structure in Segara Anakan Cilacap for the Period of 2009 and 2015. *Scr. Biol.,* 4(2): 113-118. https://doi.org/10.20884/1.sb.2017.4.2.414

Kusuma, A.H., Izzati, M. & Saptiningsih, E. 2013. Pengaruh Penambahan Arang dan Abu Sekam dengan Proporsi yang Berbeda terhadap Permeabilitas dan Porositas Tanah Liat serta Pertumbuhan Kacang Hijau (*Vigna radiata* L). *Anat. Fisiol.* 21(1): 1–9.

Lin, C.Y., Fu, C.Y., Liu, Y., Zhang, M.Q., Liu, Y., Wu, W.Y., Wang, L.X., Lin, X.H. & Fu, X.M. 2022. Assessing the changes of the monetary value of mangrove ecosystem services in China and its application. *Front. Environ. Sci.,* 10: p.1018801. https://doi.org/10.3389/fenvs.2022.1018801

Nordhaus, I., Toben, M. & Fauziyah, A. 2019. Impact of Deforestation on Mangrove Tree Diversity, Biomass and Community Dynamics in the Segara Anakan Lagoon, Java, Indonesia: A Ten-year Perspective. *Estuar. Coast. Shelf Sci.,* 227: p.106300. https://doi.org/10.1016/j.ecss.2019.106300

Nurbaya, S. 2020. *The State of Indonesia's Forests 2020*. (Efransjah, Ed.). Jakarta: Ministry of Environment and Forestry, Republic of Indonesia.

Pérez-Patricio, M., Camas-Anzueto, J.L., Sanchez-Alegría, A., Aguilar-González, A., Gutiérrez-Miceli, F., Escobar-Gómez, E., Voisin, Y., Rios-Rojas, C. & Grajales-Coutiño, R. 2018. Optical method for estimating the chlorophyll contents in plant leaves. *Sensors,* 18(2): p.650. https://doi.org/10.3390/s18020650

Permatasari, I. & Kusmana, C. 2011. Respon Pertumbuhan Semai Tancang (*Bruguiera gymnorrhiza* (L.) Lamk.) Terhadap Tingkat Penggenangan di Kawasan Mangrove Jalan Tol Sedyatmo, Jakarta Utara. *J. Silvikultur Trop.,* 2(3): 181–186.

Prambudy, A.A., Restu, I.W. & Wijayanti, N.P.P. 2023. Pola Pertumbuhan Mangrove Jenis (*Bruguiera gymnorrhiza*) dan (*Ceriops tagal*) dengan Metode Pembibitan menggunakan Substrat yang Berbeda di Pulau Serangan, Denpasar, Bali. *Curr. Trends Aquat. Sci.* VI(1): 9–15.

Prasetya, J.D., Ambariyanto, A., Supriharyono, & Purwanti, F. 2017. Mangrove Health Index as Part of Sustainable Management in Mangrove Ecosystem at Karimunjawa National Marine Park Indonesia. Adv. Sci. Lett. 23, 3277–3282. https://doi.org/10.1166/asl.2017.9155

Rahman, R., Yulianda, F., Rusmana, I. & Wardiatno, Y. 2019. Production Ratio of Seedlings and Density Status of Mangrove Ecosystem in Coastal Areas of Indonesia. *Adv. Environ. Biol.*, 13(6): 13-20. https://doi.org/10.22587/aeb. 2019.13.6.3

Ramesh, D.A., Karthi, N., Dhivya, S., Infantina, A. & Priya, P. 2022. Economic assessment mangrove ecosystems' goods services of India. *J. Soc. Rev. Dev.,* 1(2): 42–51.

Riascos, J.M., Cantera, J.R. & Blanco-Libreros, J.F. 2018. Growth and mortality of mangrove seedlings in the wettest neotropical mangrove forests during ENSO: Implications for vulnerability to climate change. *Aquat. Bot.,* 147: 34–42. https://doi.org/10.1016/j..aquabot.2018.03.002

Taek, R. 2016. Pengaruh Takaran Arang Sekam dan Guano terhadap Pertumbuhan dan Hasil Kacang Hijau (*Vigna radiata* L.). *Savana Cendana* 1(04): 121–124. https://doi.org/10.32938 /sc.v1i04.73

Tomlinson, P.B. 1994. *The Botany of Mangroves*. Cambridge: Cambridge University Press.

Usman, A.H.A., Hartoyo, A.P.P. & Kusmana, C. 2022. Use of *Rhizophora apiculata* and its cut-propagule seedling method for mangrove rehabilitation in Indonesia. *IOP Conf. Ser. Earth Environ. Sci.,* 1109(1): p.012093. https://doi.org/10.1088/1755-1315/1109/ 1/012093

Yuwono, E., Jennerjahn, T.C., Nordhaus, I., Riyanto, E.A., Sastranegara, M.H. & Pribadi, R. 2007. Ecological Status of Segara Anakan, Indonesia: A Mangrove-fringed Lagoon Affected by Human Activities. *Asian J. Water Environ. Pollut.,* 4(1): 61–70.